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(54) SENSOR WITH PRESSURE-INDUCED VARIED CAPACITANCE

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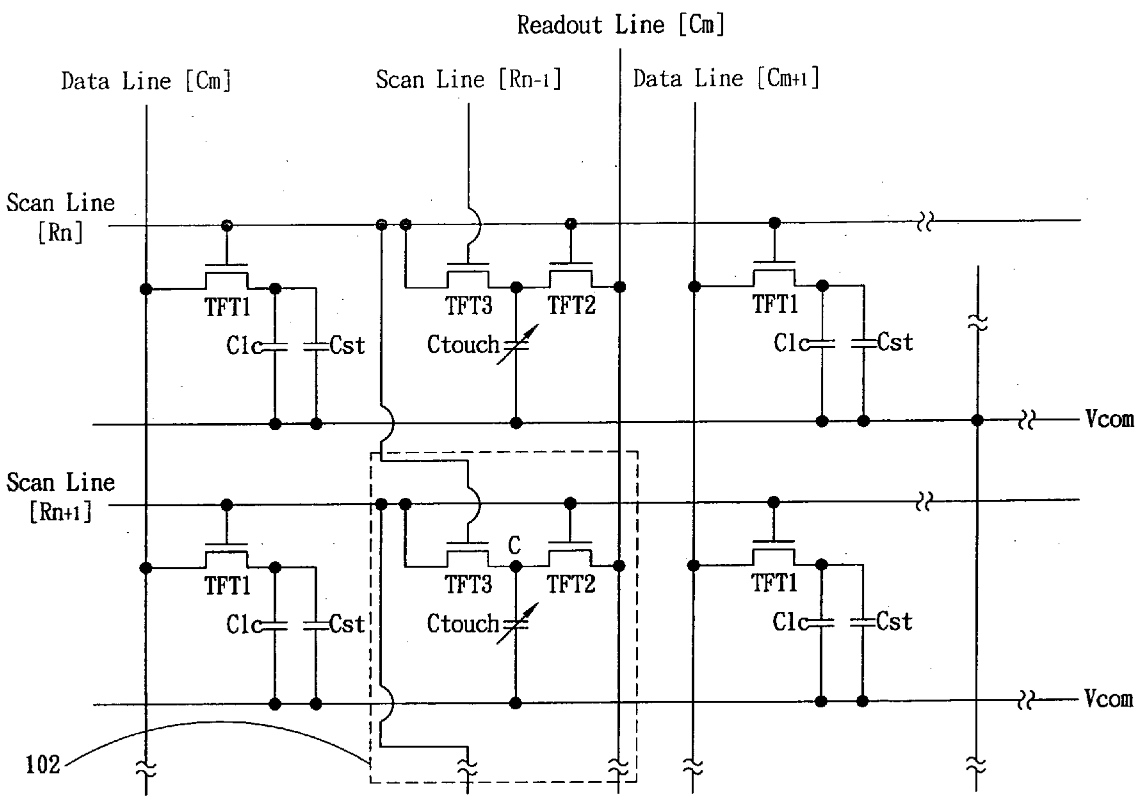
(57) ABSTRACT

A sensor with pressure-induced varied capacitance is disclosed. Each sensor pixel circuit of the sensor includes a touch capacitor, a charge TFT for storing charge at the touch capacitor according to a previous scan line, and a readout TFT for reading out voltage across the touch capacitor according to a present scan line.



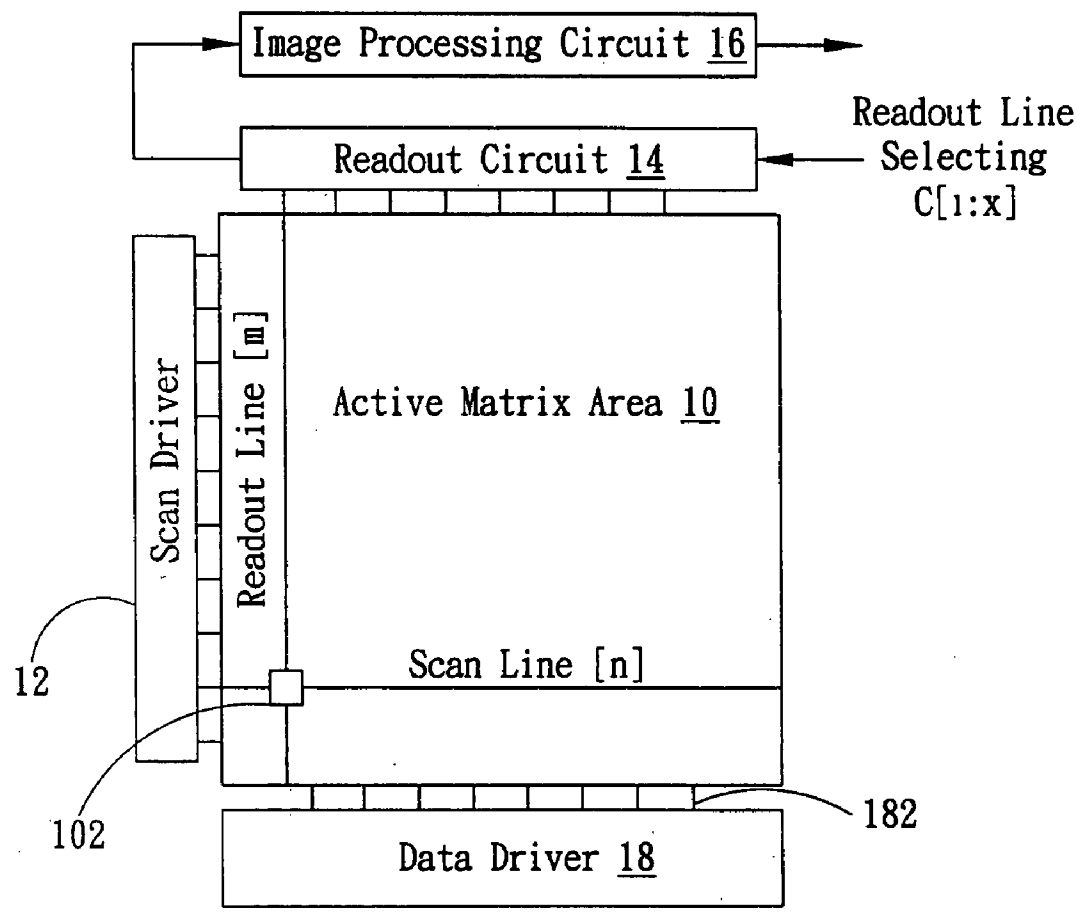


Image Processing Circuit 16
Readout Circuit 14
Readout Line
Selecting
C[1:x]
Scan Driver
Readout Line [m]
Active Matrix Area 10
Scan Line [n]
12
102
182
Data Driver 18

FIG. 1

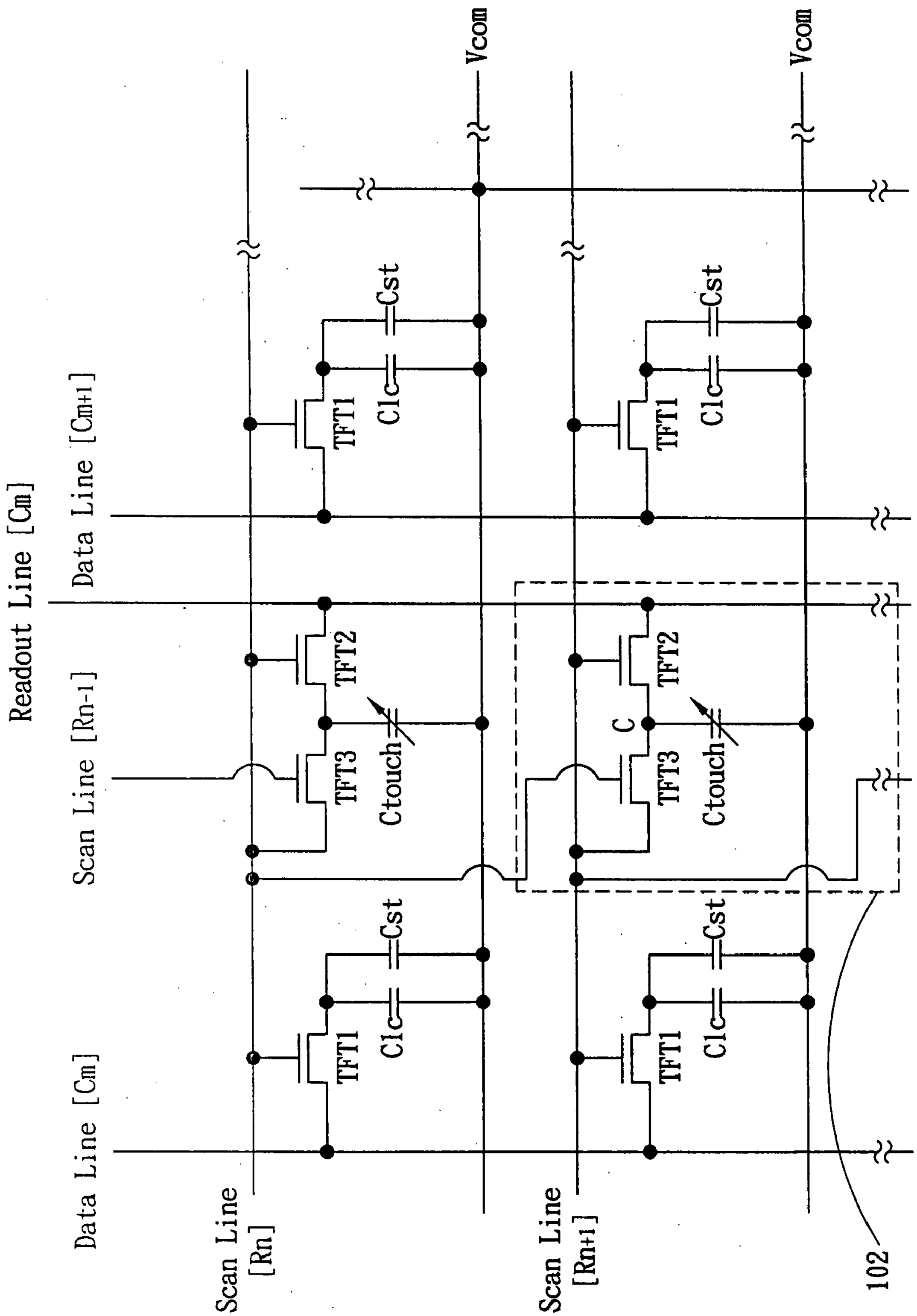

Readout Line [Cm]
Data Line [Cm+1]
Scan Line [Rn-1]
Data Line [Cm]
Scan Line [Rn]
Scan Line [Rn+1]
Vcom
Vcom
TFT1
TFT1
TFT1
TFT1
TFT2
TFT2
TFT3
TFT3
Cst
Cst
Cst
Cst
Clc
Clc
Clc
Clc
Ctouch
Ctouch
C
102

FIG. 2

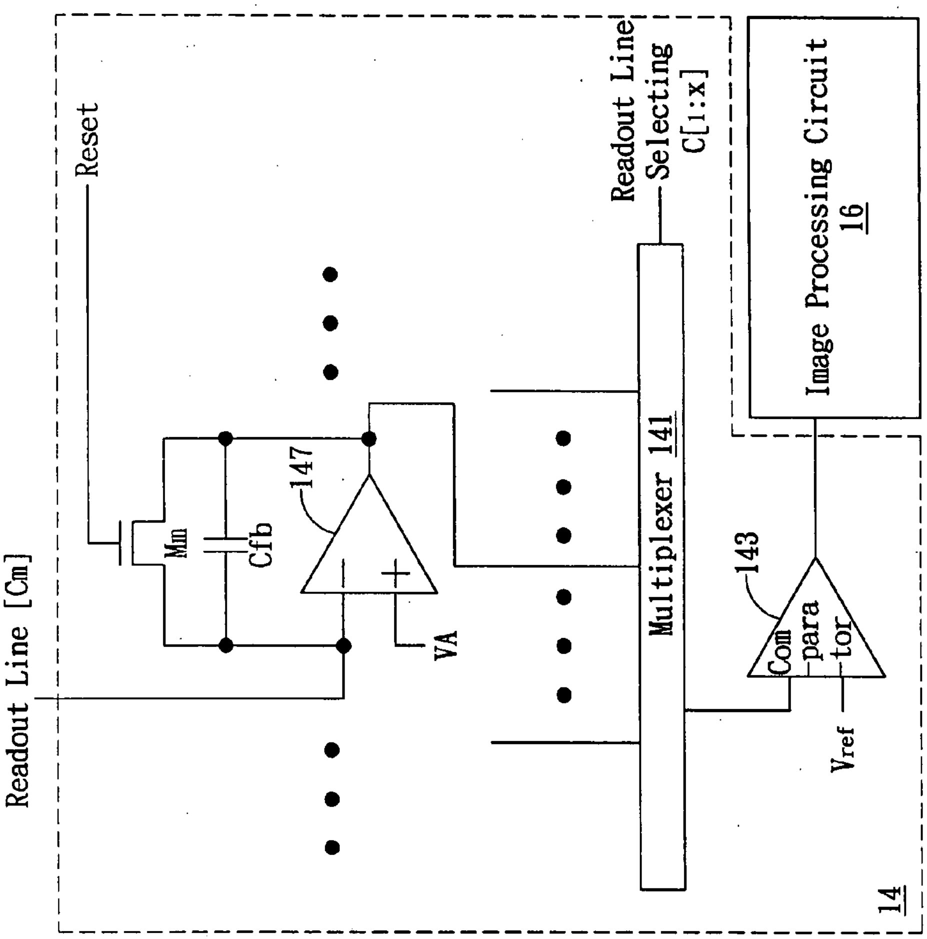

Readout Line [Cm]
Reset
Mm
Cfb
147
VA
Multiplexer 141
Readout Line Selecting C[1:x]
Image Processing Circuit 16
143
Com-para-tor
Vref
14

FIG. 3

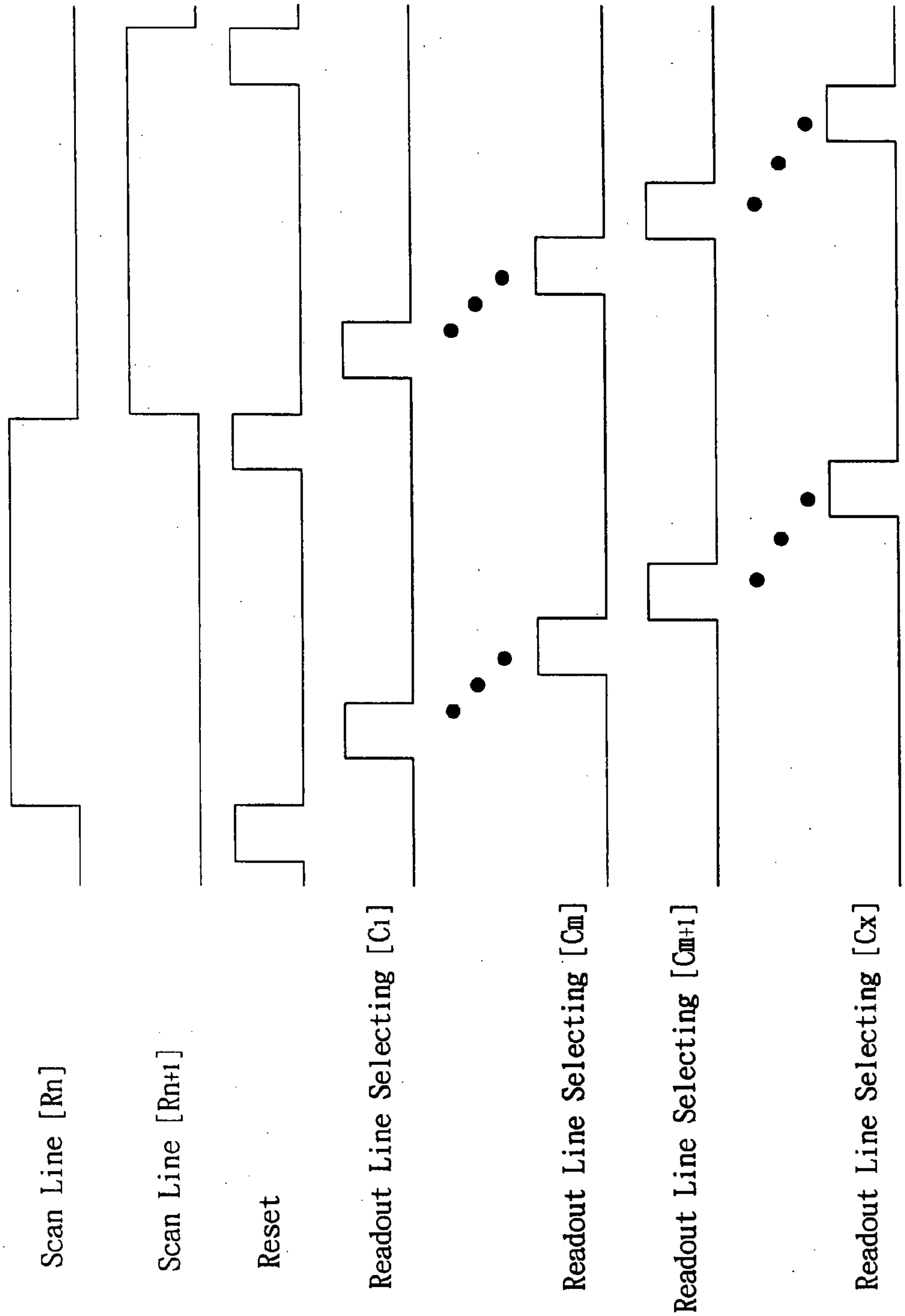

Scan Line [Rn]
Scan Line [Rn+1]
Reset
Readout Line Selecting [C1]
Readout Line Selecting [Cm]
Readout Line Selecting [Cm+1]
Readout Line Selecting [Cx]

FIG. 4

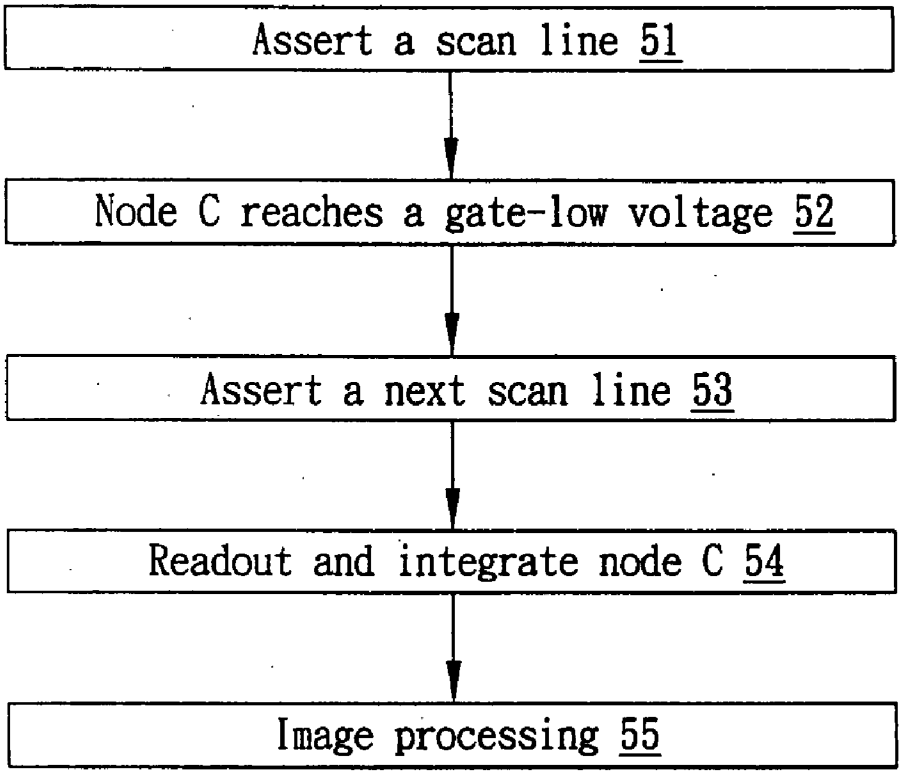

Assert a scan line 51
Node C reaches a gate-low voltage 52
Assert a next scan line 53
Readout and integrate node C 54
Image processing 55

FIG. 5

SENSOR WITH PRESSURE-INDUCED VARIED CAPACITANCE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention generally relates to a TFT sensor, and more particularly to a TFT sensor with varied capacitance induced by pressure.

[0003] 2. Description of Related Art

[0004] A touch panel integrated with a liquid crystal display (LCD) has advantages of easier and faster entry of information, and more interactive access, and thus obtains more use in portable devices such as mobile phones, personal digital assistants (PDA) or notebook computers.

[0005] In the conventional display with the touch panel, the touch panel is attached to the front of the display, which has the disadvantages of complicated assembly, increased weight, and reduced display transmission. For overcoming these disadvantages, another touch technology is disclosed to use a sensor array embedded in the thin-film-transistor (TFT) structure of an LCD.

[0006] It has been an object in the pertinent art to propose novel sensor pixel circuit architecture of the touch panel that is more simplified, more integrated while maintaining preciseness in capturing an image.

SUMMARY OF THE INVENTION

[0007] In view of the foregoing, it is an object of the present invention to provide a sensor with pressure-induced varied capacitance capable of being embedded in a touch panel and integrated with a display to precisely determine the location and image of finger(s) or other object(s).

[0008] According to the object, the present invention provides a sensor with pressure-induced varied capacitance. An active matrix area has a number of sensor pixel circuits arranged in matrix form. Scan lines and readout lines are arranged in the active matrix area such that the scan lines and the readout lines respectively cross each other at one of the sensor pixel circuits. The sensor pixel circuit includes a touch capacitor, a charge TFT for storing charge at the touch capacitor according to a previous scan line, and a readout TFT for reading out voltage across the touch capacitor according to a present scan line. According to one embodiment, a scan driver sequentially asserts the scan lines; and a readout circuit analyzes analog signals outputted from the active matrix area, and then converts the analog signals into digital signals. An image processing circuit is then used to determine the location and image of the object(s).

BRIEF DESCRIPTION OF THE FIGURES

[0009] FIG. **1** illustrates a block diagram of a TFT finger sensor according to one embodiment of the present invention;

[0010] FIG. **2** illustrates the architecture of the sensor pixel circuits of FIG. **1** according to one embodiment of the present invention;

[0011] FIG. **3** illustrates one embodiment of the readout circuit in FIG. **1**;

[0012] FIG. **4** shows an exemplary timing diagram of associated signals of the finger sensor according to the embodiment of FIG. **2** and FIG. **3**; and

[0013] FIG. **5** shows a flow chart illustrating a method of sensing a finger according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] There is one type of sensor that has varied capacitance induced by pressure of a finger on the sensor. This type of sensor utilizes the principle that the capacitance varies inversely proportional to the separation between two plates of the sensor. For example, the sensor pressed by the finger will increase its capacitance due to the decreased separation between the plates.

[0015] FIG. **1** illustrates a block diagram of a thin-film-transistor (TFT) finger sensor, particularly a sensor with pressure-induced varied capacitance, according to one embodiment of the present invention. The TFT finger sensor is embedded in a touch panel, which is further integrated with a display (not shown), such as a liquid crystal display (LCD) in this embodiment. It is appreciated by those skilled in the art that the finger sensor in this exemplary embodiment is used to capture the image of a finger or fingers, whilst the "finger" sensor is definitely not limited to capturing the finger(s).

[0016] In FIG. **1**, an active matrix area **10** contains a number of sensor pixel circuits (or sensor pixel cells) **102** arranged in matrix form for detecting the finger. The active matrix area **10** also contains a number of display pixel circuits (not shown), and some of the display pixel circuits are associatively integrated with the sensor pixel circuits. In practice, the quantity of the sensor pixel circuits in the active matrix area **10** is less than the quantity of the display pixels circuits. There are a number of (horizontal) scan lines and (vertical) readout lines arranged in the active matrix area **10** such that each sensor pixel circuit **102** at which one scan line crosses one readout line. A scan driver **12** asserts the scan lines by sequentially selecting the scan lines one at a time. In other words, a row of sensor pixel circuits **102** is asserted by associated scan line at a time. A readout circuit **14** analyzes analog signals outputted from the active matrix area **10**, and then converts the analog signals into digital signals. The converted digital signals are forwarded to an image processing circuit **16** to determine the location and image of a finger or fingers. Data driver **18** is specifically used for driving the display pixel circuits via data lines **182** to display image on the LCD.

[0017] FIG. **2** illustrates the architecture of the sensor pixel circuits **102** of FIG. **1** according to one embodiment of the present invention. In the figure, only two sensor pixel circuits **102** are shown for the purpose of illustration, while other sensor pixel circuits **102** not shown could be well built in the same manner. Display pixel circuits each consisting of a TFT**1** and capacitors C_{lc} and C_{st} are also shown in the figure. In the embodiment, Scan Lines are commonly used among the display pixel circuits and the sensor pixel circuits **102**, while the display pixel circuits use specific data line, e.g., Data Line [C_m], for display, and the sensor pixel circuits use specific readout line, e.g., Readout Line [C_m], for sensor.

[0018] Each sensor pixel circuit **102** includes a charge TFT (TFT**3**), a readout TFT (TFT**2**), and a touch capacitor C_{touch} connected as shown. A scan line is associated with and connected to the readout TFTs (TFT**2**) of all of the sensor pixel circuits **102** on the same row. In this exemplary figure, Scan Line [R_{n+1}] is connected to the readout TFTs (TFT**2**) of the sensor pixel circuits **102** on the (n+1)-th row. A scan line of previous row is associated with and connected to the charge TFTs (TFT**3**) of all of the sensor pixel circuits **102** on the same row. In this exemplary figure, Scan Line [R_n] is connected to the charge TFTs (TFT3) of the sensor pixel circuits **102** on the (n+1)-th row. A number of readout lines each is respectively associated with and connected to corresponding sensor pixel circuits **102** on the same column. In this exemplary figure, Readout Line [C_m] is connected to sensor pixel circuits **102** on the m-th column.

[0019] Still referring to FIG. **2**, specifically speaking, with respect to the readout TFT (TFT**2**), one of the source/drain is electrically connected to the associated Readout Line [C_m], the gate is electrically connected to the associated Scan Line [R_{n+1}] of the present row, and the other one of the source/drain is electrically connected to the charge TFT (TFT**3**) and the touch capacitor C_{touch} at a node C. With respect to the charge TFT (TFT**3**), one of the source/drain is electrically connected to the readout TFT (TFT**2**) at the node C, the gate is electrically connected to the associated Scan Line [R_n] of previous row, and the other one of the source/drain is electrically connected to the associated Scan Line [R_{n+1}] of the present row. With respect to the touch capacitor C_{touch}, one plate is electrically connected to the node C and the other plate is electrically connected to a common voltage V_{com}.

[0020] FIG. **3** illustrates one embodiment of the readout circuit **14** in FIG. **1**. A number of readout lines respectively corresponding to columns of sensor pixel circuits are connected and inputted to integrating circuits (such as integrator operational amplifiers (OP-Amp)) **147**. A feedback capacitor C_{fb} is connected between the output and the inverting input of each integrator OP-Amp **147**, while the non-inverting input of the integrator OP-Amp **147** is connected with a predetermined reset voltage VA. The source and drain of a reset transistor M is connected across the ends of the feedback capacitor C_{fb}, and its gate electrode is connected to a Reset signal. The output of the integrator OP-Amp **147** is further connected to a multiplexer **141**. One of the outputs of the integrator OP-Amps **147** is selected in turn according to Readout Line Selecting signal. The selected analog signal is converted into digital signal by comparing the selected analog signal with a predetermined reference voltage V_{ref} through a comparator **143**, resulting in an N-bit output. In an exemplary embodiment, the output of the comparator **143** has one bit (i.e., N=1) to indicate either presence of a touched finger or the absence of a finger. The output of the comparator **143** is further fed to the image processing circuit **16** for further processing.

[0021] FIG. **4** shows an exemplary timing diagram of associated signals of the finger sensor according to the embodiment of FIG. **2** and FIG. **3**. In one line scan, for example the line scan for the n-th row as shown in the figure, while the Scan Line [R_n] is asserted, Readout Line Selecting [C_1]-[C_x] signals (to the readout circuit **14**) respectively associated with columns of sensor pixel circuits **102** are asserted in sequence. The Reset [n] signal is asserted at the end of the assertion of each scan line to reset the output of the integrator OP-Amp **147** to VA through the reset transistor M, and the integrator OP-Amp **147** is ready for performing integration for the next scan line.

[0022] The operation of the finger sensor of FIG. **2** and FIG. **3** will be specifically described below while referring to FIG. **4**. When a Scan Line [R_n] is asserted, the charge TFTs (TFT**3**) on the next row (i.e., (n+1)-th row) are turned on, and charge QC is then stored at each touch capacitor C_{touch} due to an (un-asserted) gate-low voltage VGL at the unasserted Scan Line [R_{n+1}]. The voltage at the node C thus reaches VGL. The charge QC and the gate-low voltage VGL have the following relationship:

$$QC = C_{touch} * VGL$$

where the value of C_{touch} with presence of a touched finger is greater than the value of C_{touch} with absence of a finger, because the gap between electrode plates of the touch capacitor C_{touch} would be smaller if pressed by the finger or other objects.

[0023] Subsequently, when a next Scan Line [R_{n+1}] is asserted, the readout TFTs (TFT**2**) on the (n+1)-th row are turned on, and the voltage VGL at the node C is then readout through corresponding readout line. The readout voltage is then integrated by the integrator OP-Amp **147**. The integrated output V_{out} of the integrator OP-Amp **147** is:

$$V_{out} = \mathrm{VA} + \frac{(V_{ref} - VGL) \times C_{touch}}{C_{fb}}$$

[0024] Therefore, the absence or presence of a finger could be distinguished according to different V_{out} due to different C_{touch}.

[0025] FIG. **5** shows a flow chart illustrating a method of sensing a finger according to one embodiment of the present invention. At the outset, in step **51**, a Scan Line [R_n] is asserted, and the node C then reaches a gate-low voltage VGL via the charge TFT (TFT3) (step **52**). Subsequently, a next Scan Line [R_{n+1}] is asserted (step **53**), and the voltage at the node C is readout via the readout TFT (TFT**2**) by the readout circuit **14** (step **54**), which integrates and converts the analog signals into digital signals. The absence or presence of a finger could be distinguished according to different output V_{out} of the integrator OP-Amp **147** due to different C_{touch}. The converted digital signals are subsequently, in step **55**, forwarded to the image processing circuit **16** to determine the location and image of the finger(s).

[0026] Although specific embodiments have been illustrated and described, it will be appreciated by those skilled in the art that various modifications may be made without departing from the scope of the present invention, which is intended to be limited solely by the appended claims.

What is claimed is:

1. A sensor, comprising:

an active matrix area having a plurality of sensor pixel circuits arranged in matrix form; and

a plurality of scan lines and readout lines arranged in the active matrix area such that the scan lines and the readout lines respectively cross each other at one of the sensor pixel circuits,

wherein each of the sensor pixel circuits includes a touch capacitor, a charge TFT for storing charge at the touch capacitor according to a previous scan line, and a readout TFT for reading out voltage across the touch capacitor according to a present scan line.

2. The sensor according to claim **1**, further comprising a scan driver for sequentially asserting the scan lines.

3. The sensor according to claim **1**, further comprising a readout circuit for analyzing analog signals outputted from the active matrix area, and then converting the analog signals into digital signals.

4. The sensor according to claim **1**, further comprising an image processing circuit for determining location and image of the object or objects.

5. The sensor according to claim **3**, wherein the readout circuit comprises:

a plurality of integrating circuits connected to receive output of the active matrix area, wherein the integrating circuits respectively connect to the readout lines.

6. The sensor according to claim **5**, wherein each of the integrating circuits comprises:

an integrator operational amplifier;

a feedback capacitor connected between output and inverting input of the integrator operational amplifier;

a predetermined reset voltage connected to non-inverting input of the integrator operational amplifier; and

a reset transistor having source and drain connected across ends of the feedback capacitor, and a gate connected to a reset signal.

7. The sensor according to claim **6**, wherein the readout circuit further comprises:

a multiplexer for inputting the outputs of the integrator operational amplifiers, among which one of the outputs is selected according to readout line selecting signals; and

a comparator for comparing the analog signal of the selected readout line with a predetermined reference voltage.

8. The sensor according to claim **1**, wherein:

the readout TFT having one of source/drain being electrically connected to associated readout line, gate being electrically connected to the associated scan line of present row, and other one of the source/drain being electrically connected to the charge TFT and the touch capacitor at a node;

the charge TFT having one of source/drain being electrically connected to the readout TFT at the node, gate being electrically connected to the associated scan line of previous row, and the other one of the source/drain being electrically connected to the associated scan line of the present row; and

the touch capacitor having one plate being electrically connected to the node and other plate being electrically connected to a common voltage.

9. A sensing method, comprising:

asserting a scan line of previous row;

reaching a low voltage at a node of present row;

asserting a scan line of present row;

reading out voltage at the node of the present row; and

integrating the readout voltage, thereby absence or presence of an object is distinguishable according to different integrated readout voltage due to different touch capacitance at the node.

10. The sensing method according to claim **9**, further comprising:

converting analog signals of the integrated readout voltages into digital signals.

11. The sensing method according to claim **10**, further comprising:

processing the digital signals to determine location and image of the object or objects.

* * * * *